Vapor Intrusion

(to Indoor Air) from Waste Sites

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Regional Risk Assessors Training & Conference

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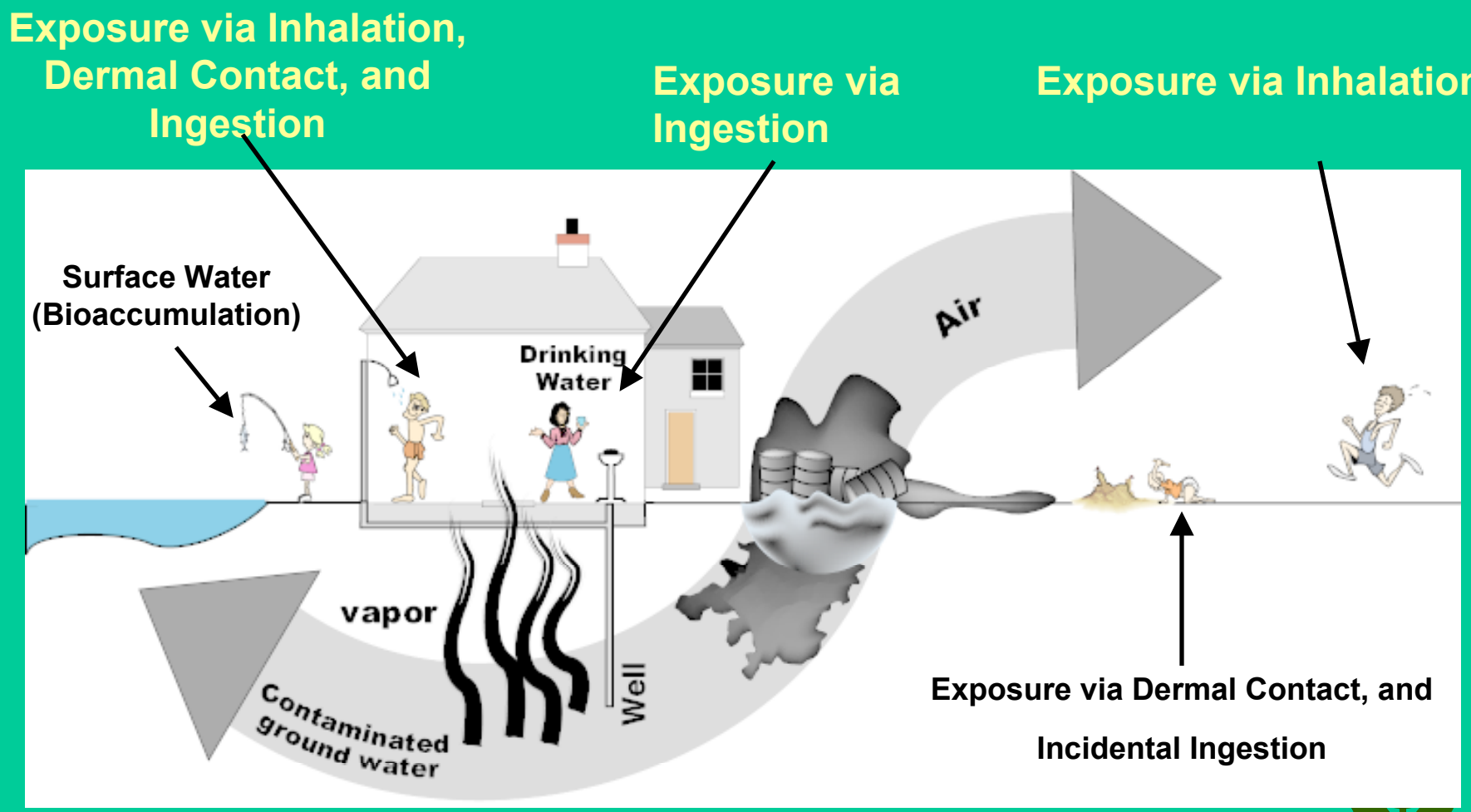
EPA - Office of Solid Waste

RCRA Corrective Action (CA) Environmental Indicators (EI)

- Environmental Indicators (EI) are how we measure progress
- Impacts of contaminated media on indoor air is one of the most difficult exposure pathways to be assessed:
  - Is there a potential problem?
  - Do we need to collect additional data to assess?
  - Do we need to collect indoor air samples?
  - What do the indoor air results mean?

Some Principal Pathways to be Considered for "Current Human Exposures Under Control"



Summary Exposure Pathway Evaluation Table

(analysis for "completeness" of pathways)

- Potential[ly Applicable] Human Receptors (Under Current Conditions)

"Contam." Media	**Residents**	**Workers**	**Day-Care**	Construction	Trespassers	Recreation	Food3
Groundwater	___	___	___	___			___
Air (indoors)	_?_	_Y_	_N_				
Soil (surface, e.g., <2 ft)	___	___	___	___	___	___	___
Surface Water	___	___			___	___	___
Sediment	___	___			___	___	___
Soil (subsurface e.g., >2 ft)				___			___
Air (outdoors)	___	___	___	___	___		

Three Myths in the traditional framework for acute air impacts

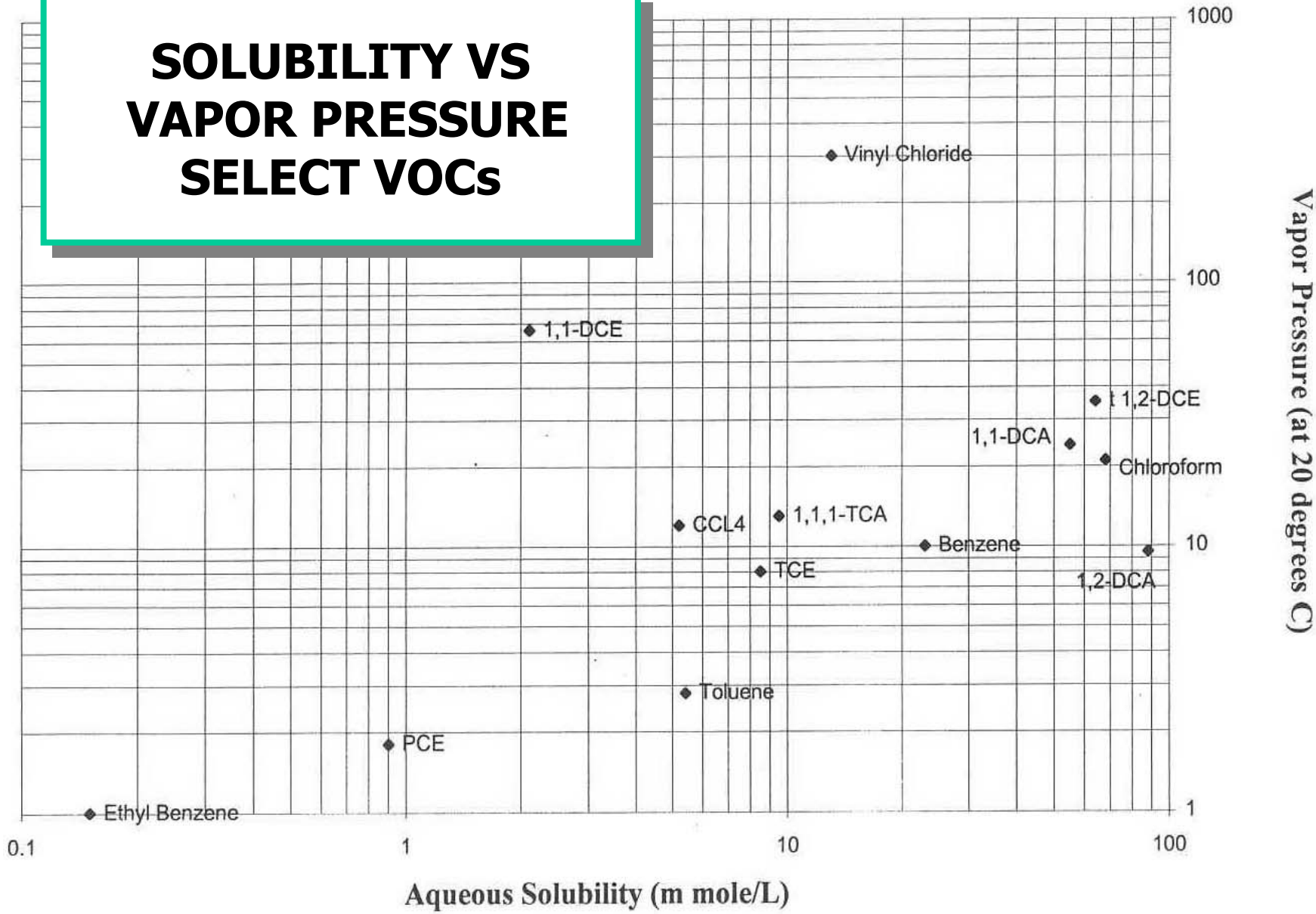
- 3 Rules of Thumb have been used to help identify the potential for indoor air concerns in cleanups (i.e., these conditions are needed):
  - 1) High concentrations (e.g, ppm or NAPL VOC)
  - 2) Shallow water table (few ft or wet basements)
  - 3) Basements (i.e., homes, apartments, offices, etc., without basements are not of concern)
- All three shown to be wrong (when considering chronic exposures) at two sites in Colorado.

Brief History of Chronic Air Issues

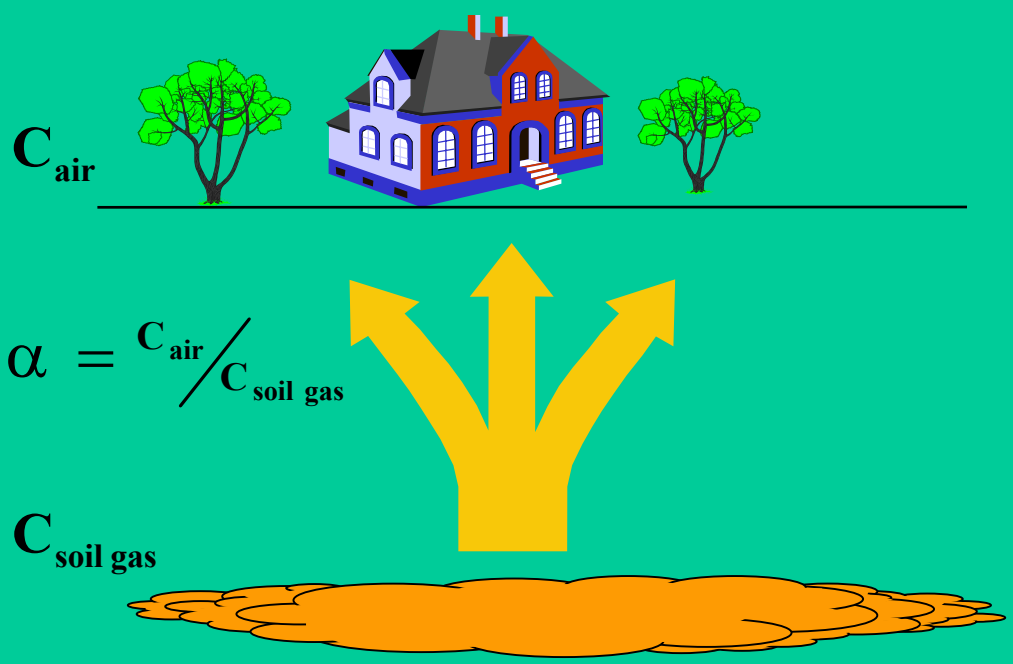
(selected Regulatory and Scientific developments (known by CAPB))

- MA DEP address acute & chronic indoor air concerns in cases and in MA NCP
- Johnson & Ettinger publish predictive model
- CT DEP regulates gw & sg for protection of indoor air (assuming chronic exposures)
- Air/Superfund Indoor Air Impacts Guidance
- Colorado DPH&E public request at CDOT
- CDPH&E treats exposures from vapors in indoor air equivalent to other contaminated media
- 1999 National RCRA Meeting - C. Johnson

SOLUBILITY VS VAPOR PRESSURE SELECT VOCs



Transport of VOCs in Vadose Zone Conceptual Model



- Mixing in Breathing Zone
- Convection (near building)
- Aerobic Biodegradation
- Diffusion
- Phase Partitioning (equilibrium)
- *(Su bsurface organism “homes)

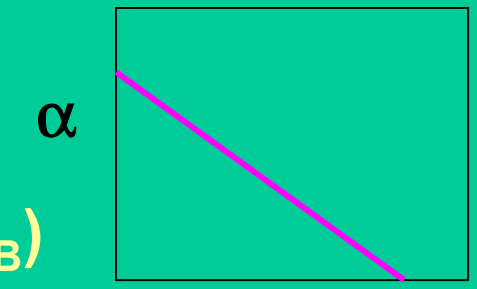
Risk is proportional to (α) x ($C_{soil\ gas}$)

Significant Factors Influencing Vapor Migration to Indoor Air

Building factors

Mixing

- Parameters affecting Q_{Bldg}
  - ER, Building Volume (A_B and L_B)



Convection

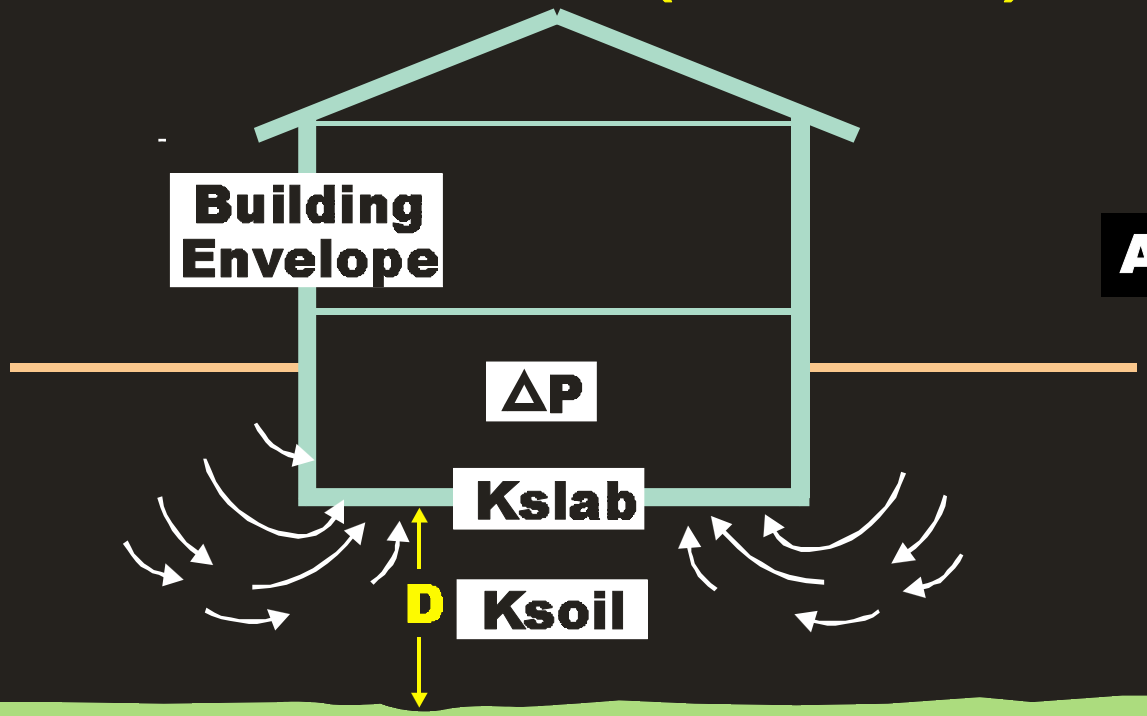
- Parameters affecting Q_{soil}

  ΔP, k_v, A_{crk} (η and A_B), Z_{crk}, L_{crk}

Diffusion (through building foundation)

- Parameters affecting D_{bldg}^{eff}
  - A_{crk} (η and A_B), D_{crk}^{eff}, L_{crk}

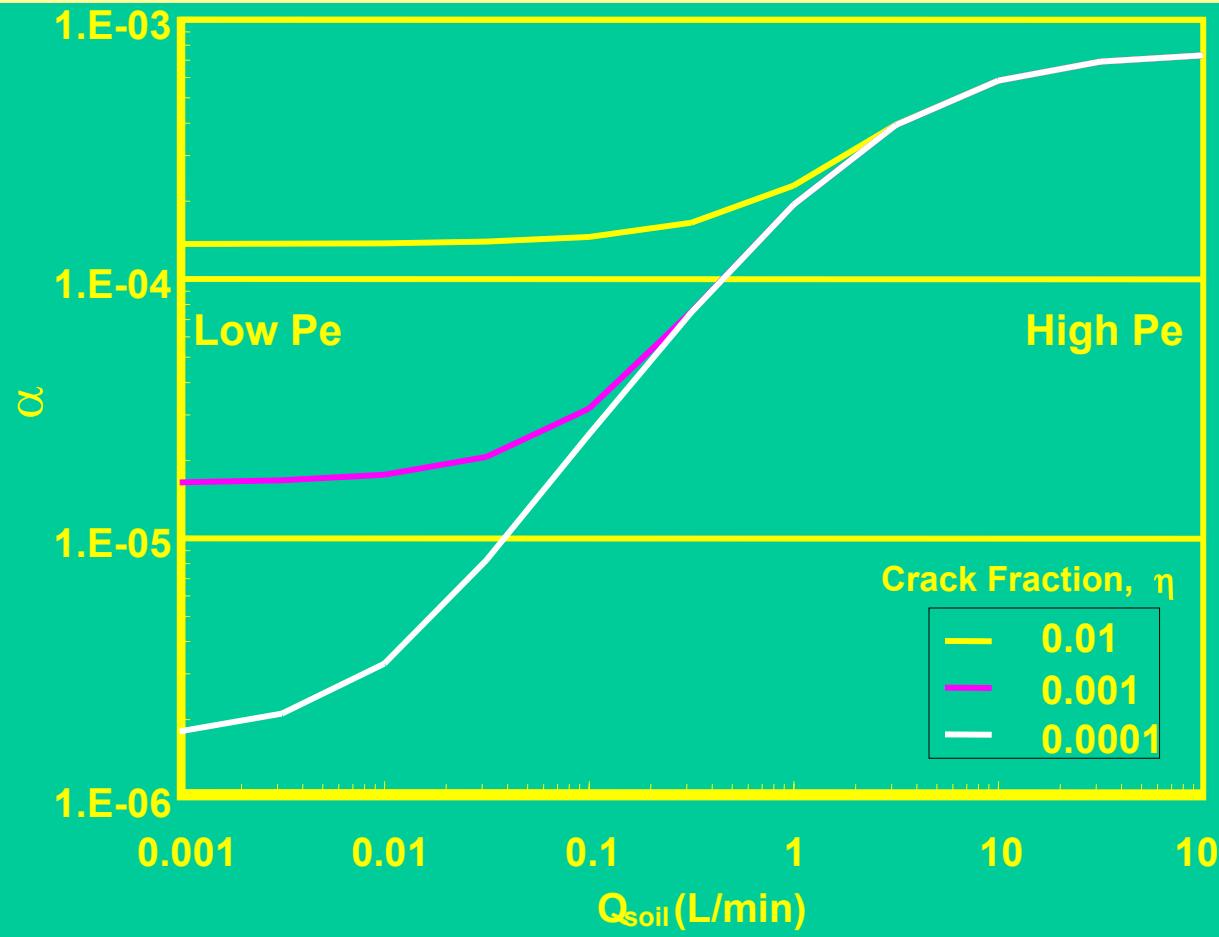
BUILDING FOUNDATION & SUBSOIL COMPARTMENT (Near-field)



CONTRIBUTION OF ADVECTIVE FLUX TO VOC INTRUSION GREATEST WHEN

- **ΔP, Ksoil, Kslab, high**
- **D low**
- **Tight above-grade building envelope**

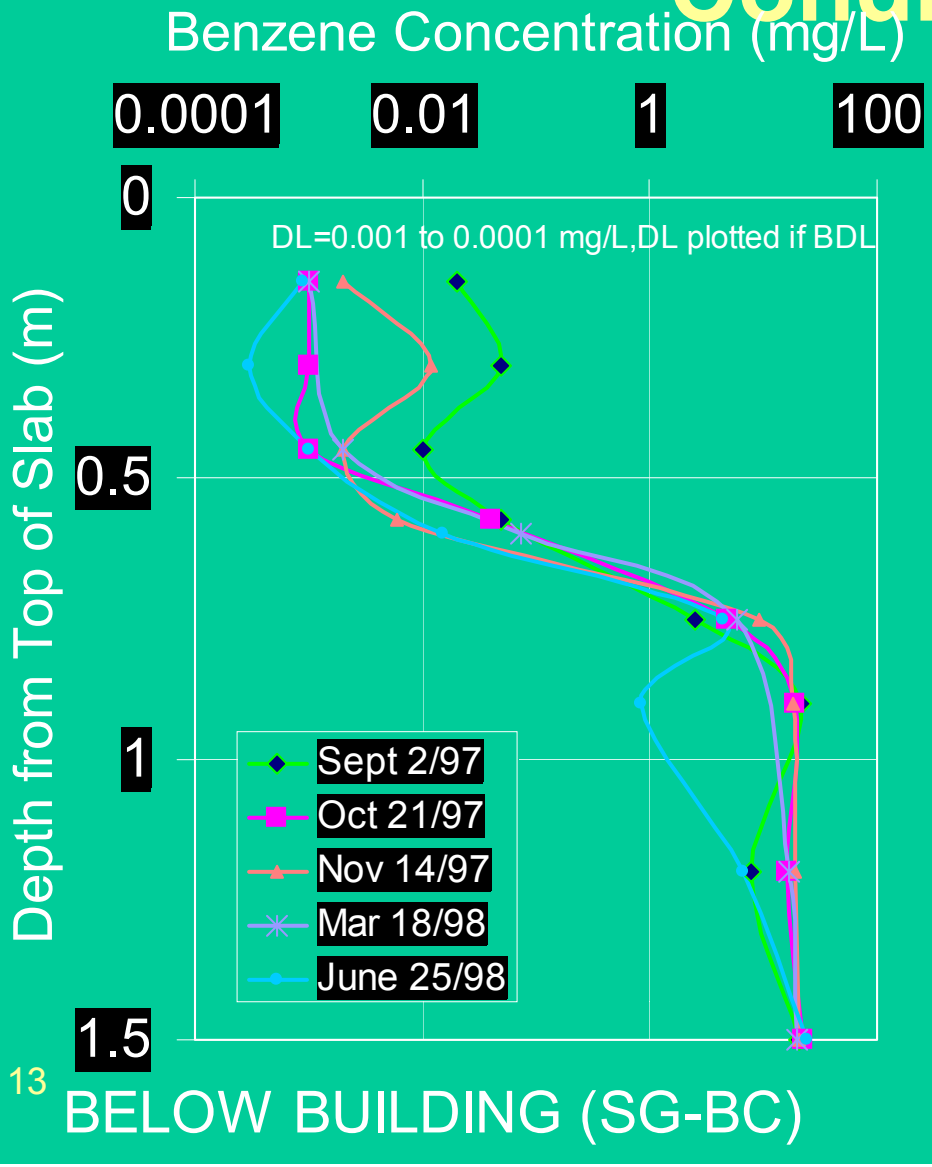
Effect of Convection on Attenuation Factor



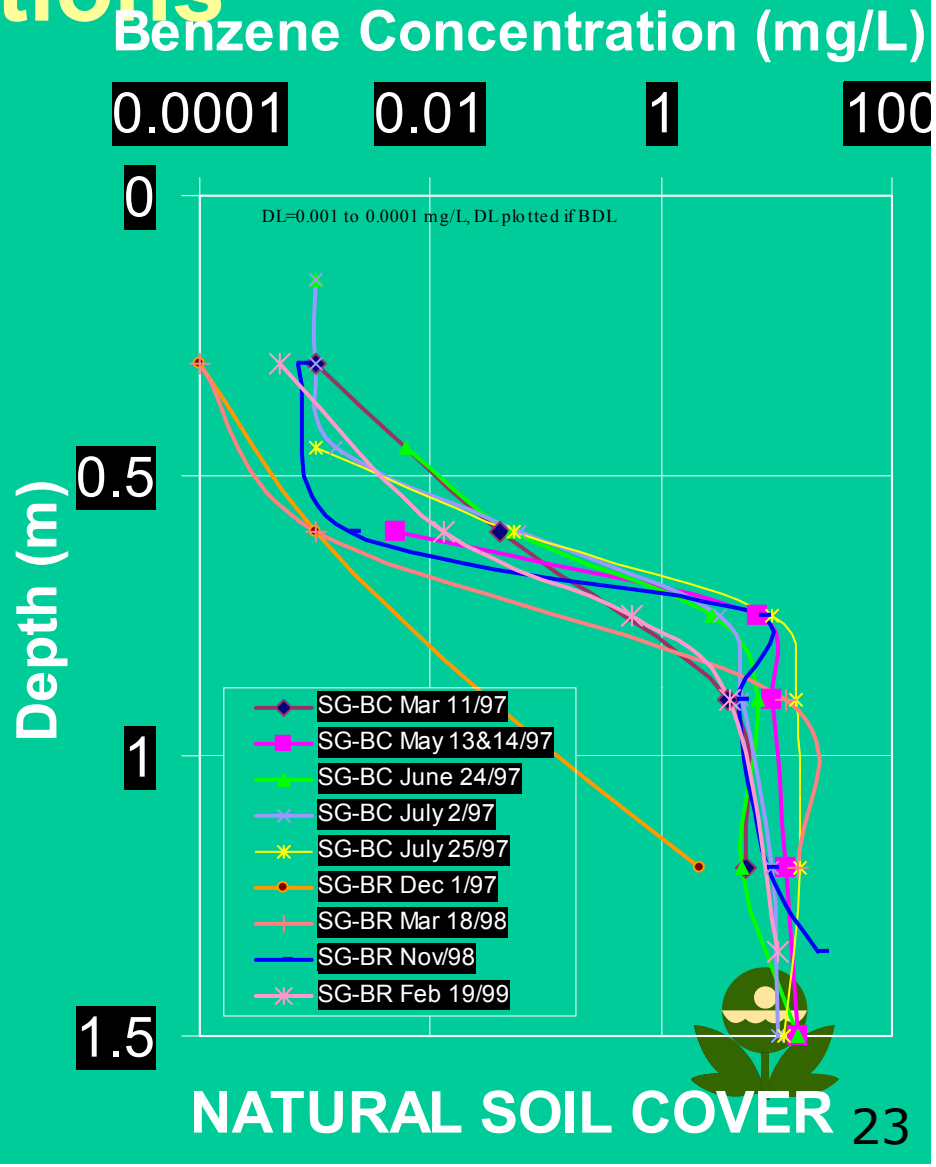
$$Pe = \frac{\text{Convection}}{\text{Diffusion}}$$

- Attenuation factor increases with higher Pe
- Effect of D_{air}^{eff} is observed at low Pe

Benzene Vapour Concentrations Below Centre Building - Natural Conditions

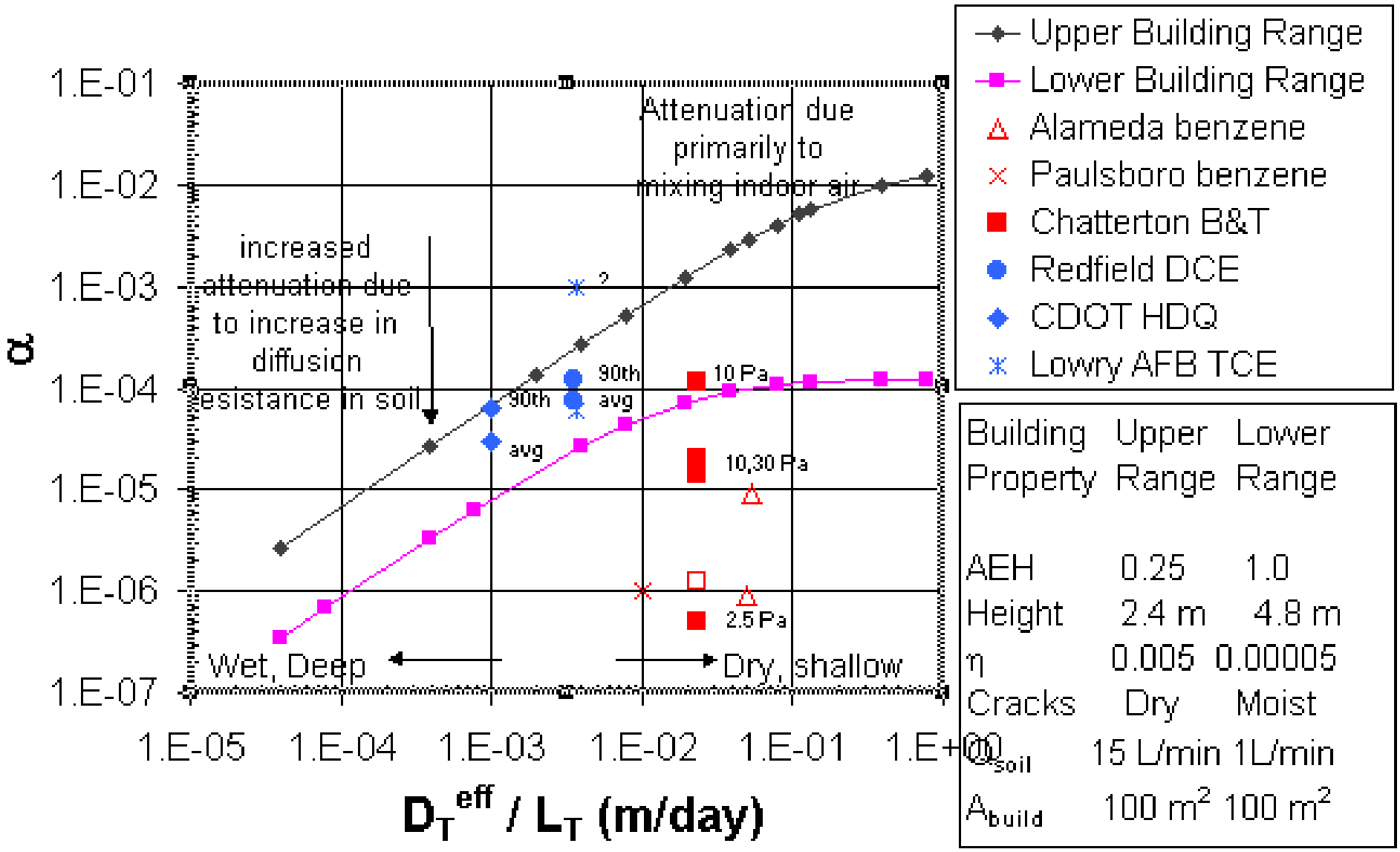


BELOW BUILDING (SG-BC)



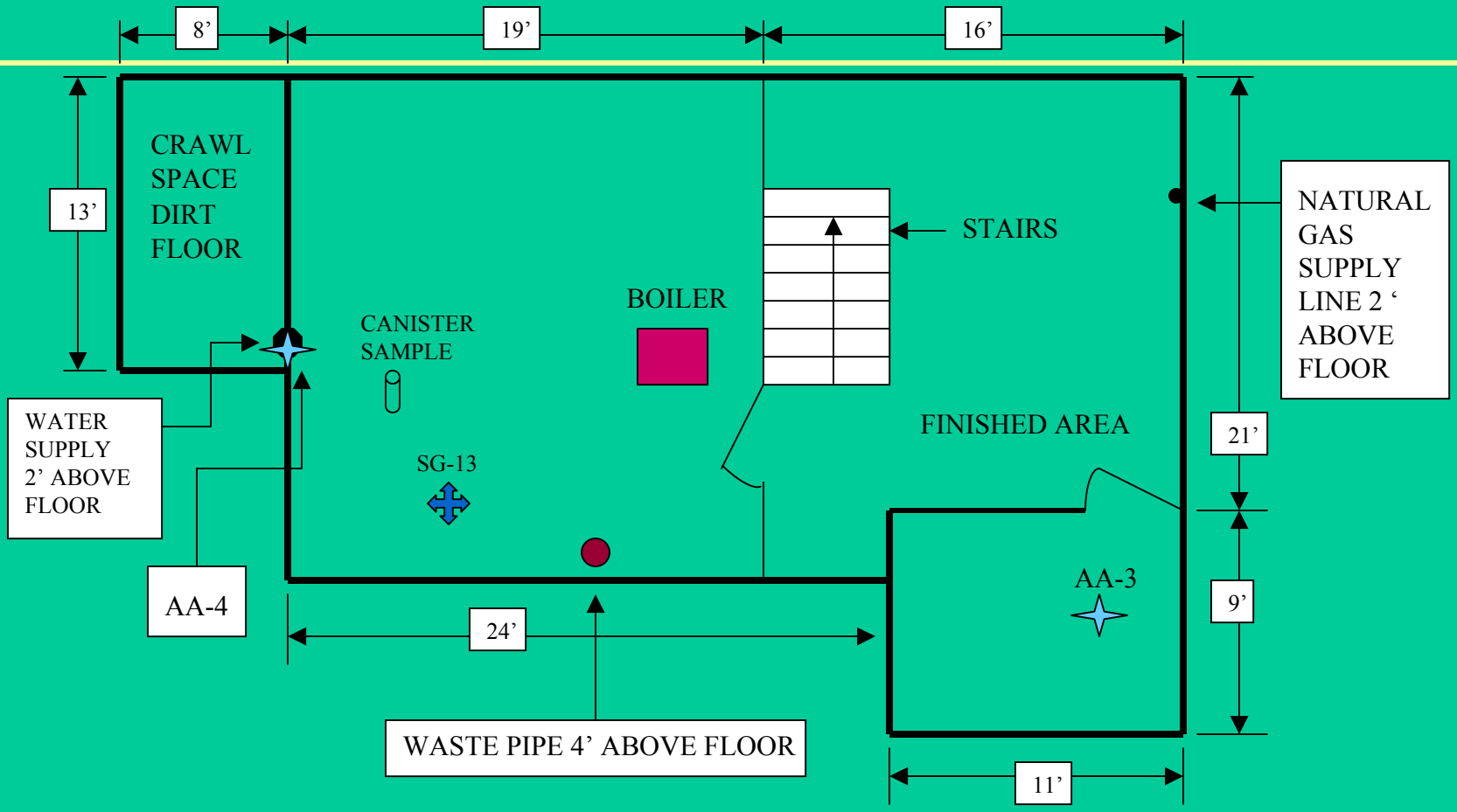
NATURAL SOIL COVER

α Comparison - Measured to Predicted (J&E)



Building Property	Upper Range	Lower Range
AEH	0.25	1.0
Height	2.4 m	4.8 m
η	0.005	0.00005
Cracks	Dry	Moist
Q_{soil}	15 L/min	1L/min
A_{build}	100 m^2	100 m^2

HOMESTEAD AVENUE



Scale: 1/4” = 2’

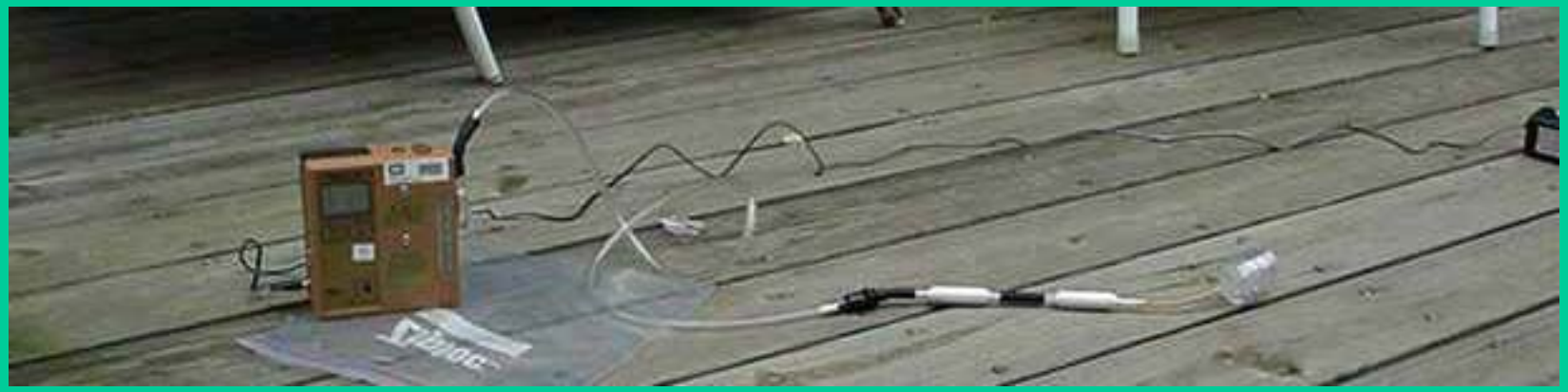
AA-3 AND AA-4 INDOOR AIR GRAB SAMPLES

SG-13 SOIL GRAB SAMPLE

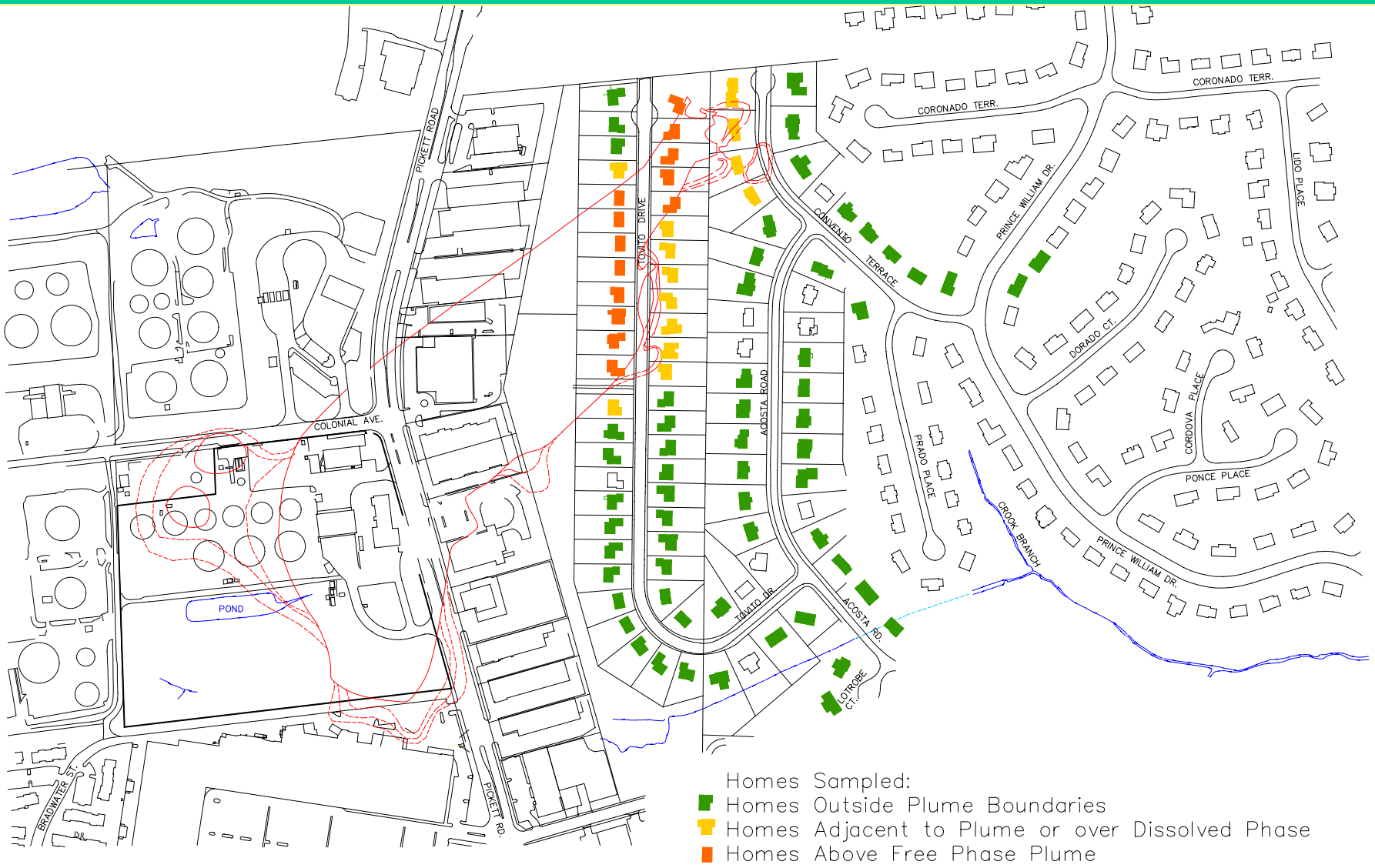
AIR SAMPLING METHOD

- SUMMA CANISTER
- EPA Method TO- 15
- High Resolution
- Selective Ion Monitoring

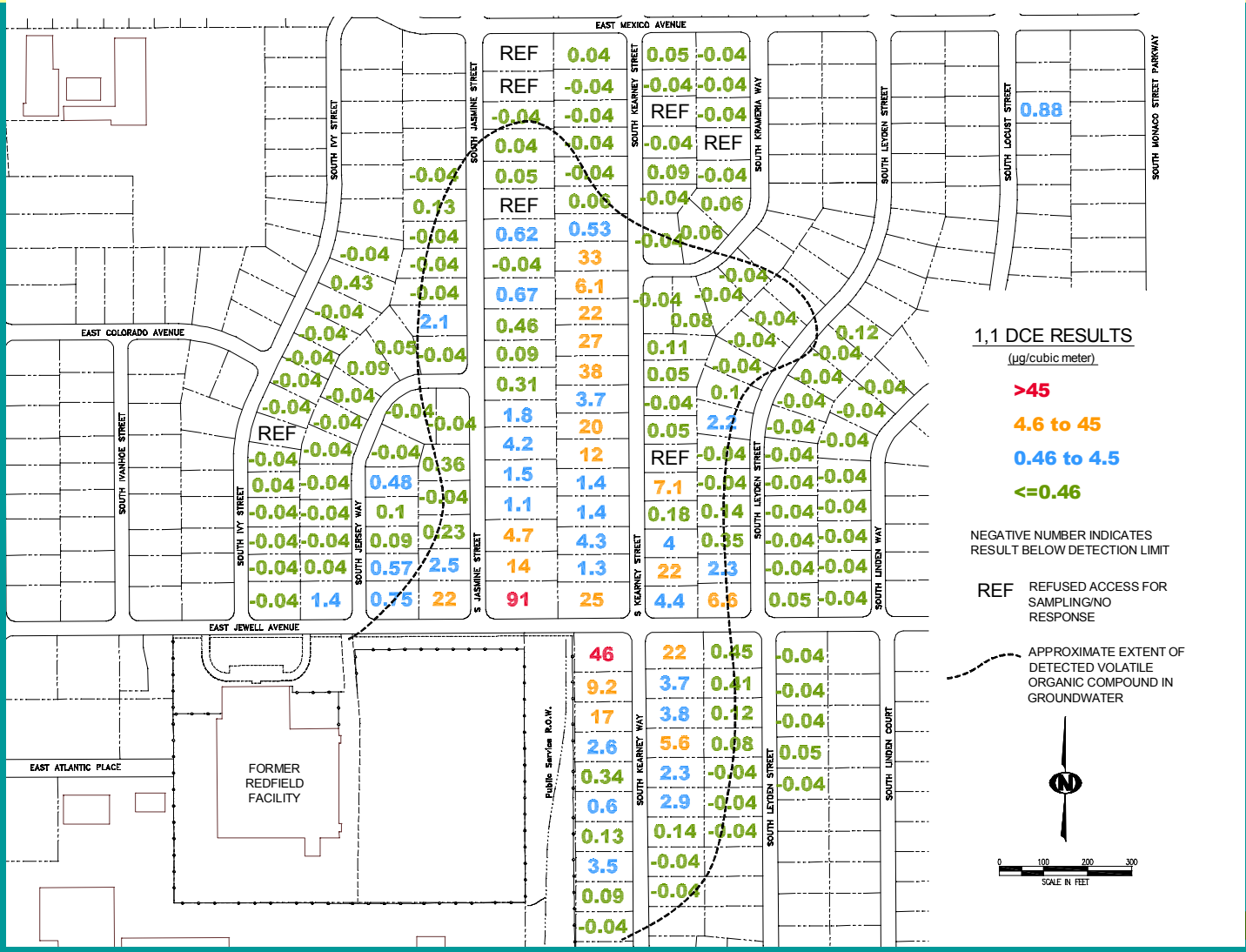
Tenax Tubes

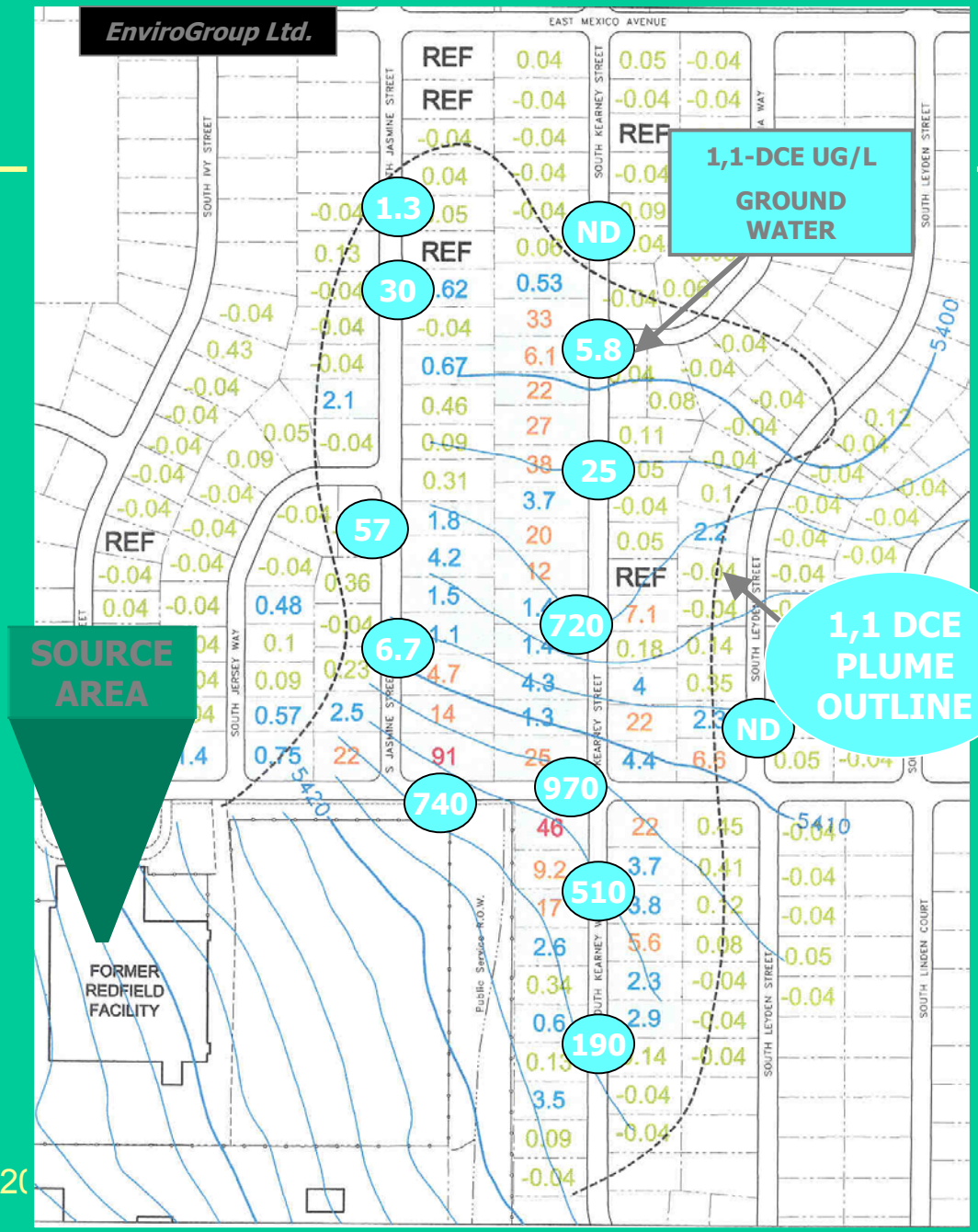


Location of Homes Sampled



1,1 DCE


EAST MEXICO AVENUE
EAST COLORADO AVENUE
EAST JEWELL AVENUE
EAST ATLANTIC PLACE
SOUTH IVY STREET
SOUTH JASMINE STREET
SOUTH KEARNEY STREET
SOUTH KRAMERIA WAY
SOUTH LEYDEN STREET
SOUTH LOCUST STREET
SOUTH MONACO STREET PARKWAY
SOUTH IVANHOE STREET
SOUTH JERSEY WAY
S JASMINE STREET
S KEARNEY STREET
SOUTH LINDEN WAY
SOUTH LINDEN COURT
Public Service R.O.W.
FORMER REDFIELD FACILITY
1,1 DCE RESULTS
(µg/cubic meter)
>45
4.6 to 45
0.46 to 4.5
<=0.46
NEGATIVE NUMBER INDICATES RESULT BELOW DETECTION LIMIT
REF
REFUSED ACCESS FOR SAMPLING/NO RESPONSE
APPROXIMATE EXTENT OF DETECTED VOLATILE ORGANIC COMPOUND IN GROUNDWATER
N
0 100 200 300
SCALE IN FEET



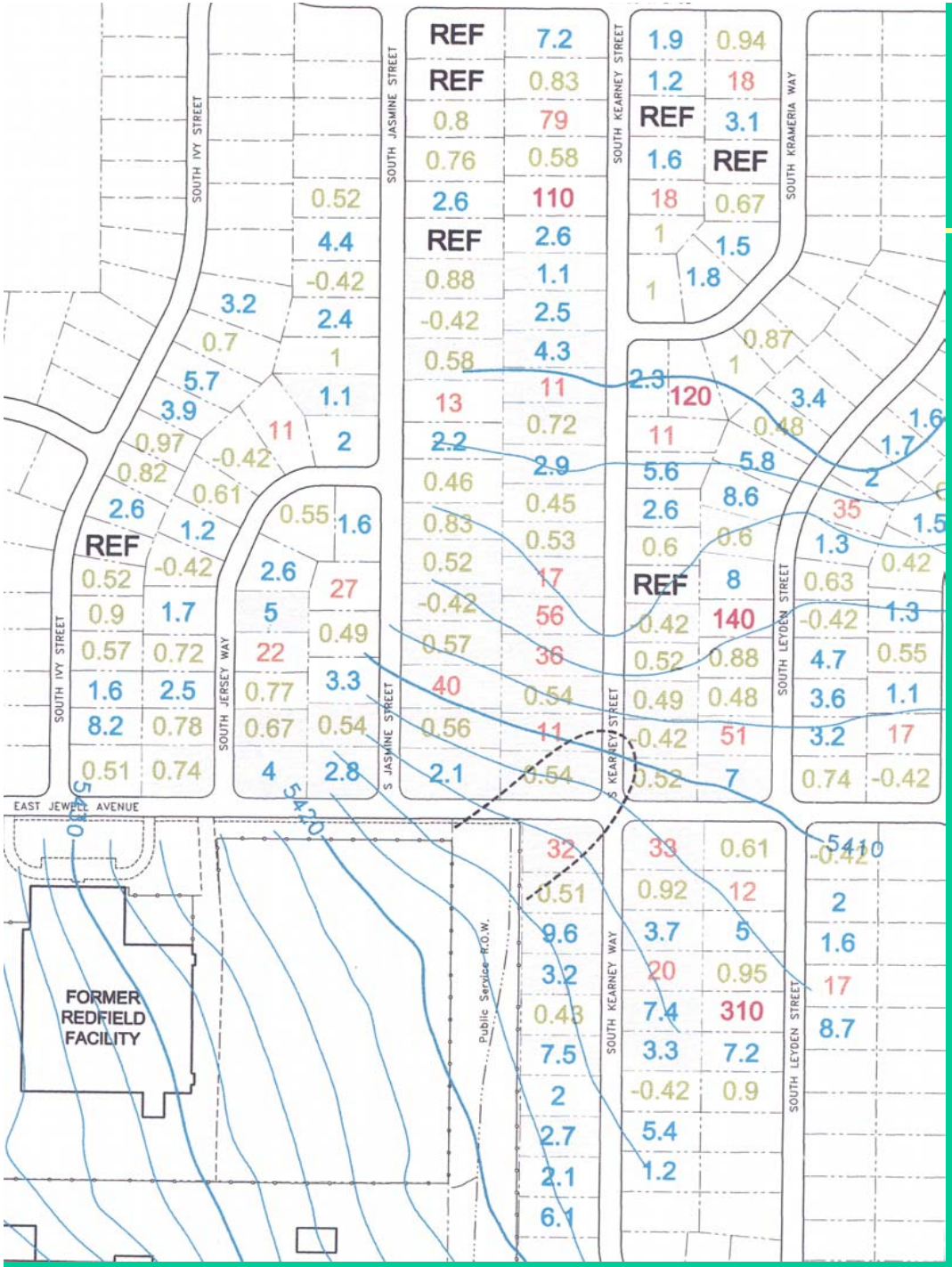
REDFIELD SITE

170 HOMES TESTED

DEPTH TO GW >20'

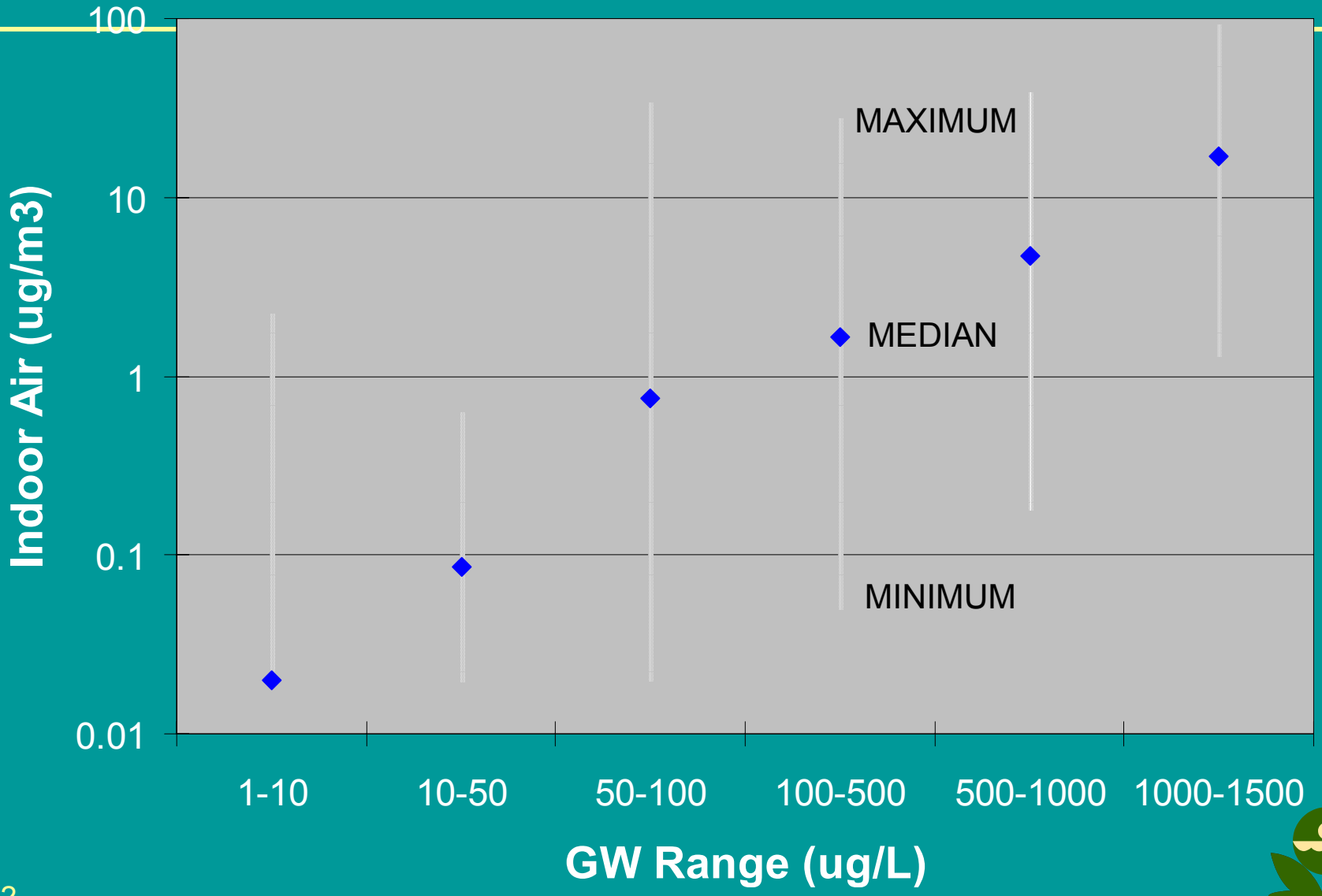
62 REMEDIATION SYSTEMS INSTALLED IN SINGLE FAMILY HOMES

INDOOR AIR
1,1-DCE UG/M³
RED > 45
ORANGE 4.6 TO 45
BLUE 0.46 TO 4.5



- METHYLENE CHLORIDE
- Initial Indoor-Air Concentrations

GW/IA CORRELATION



CDOT DATA CORRELATIONS

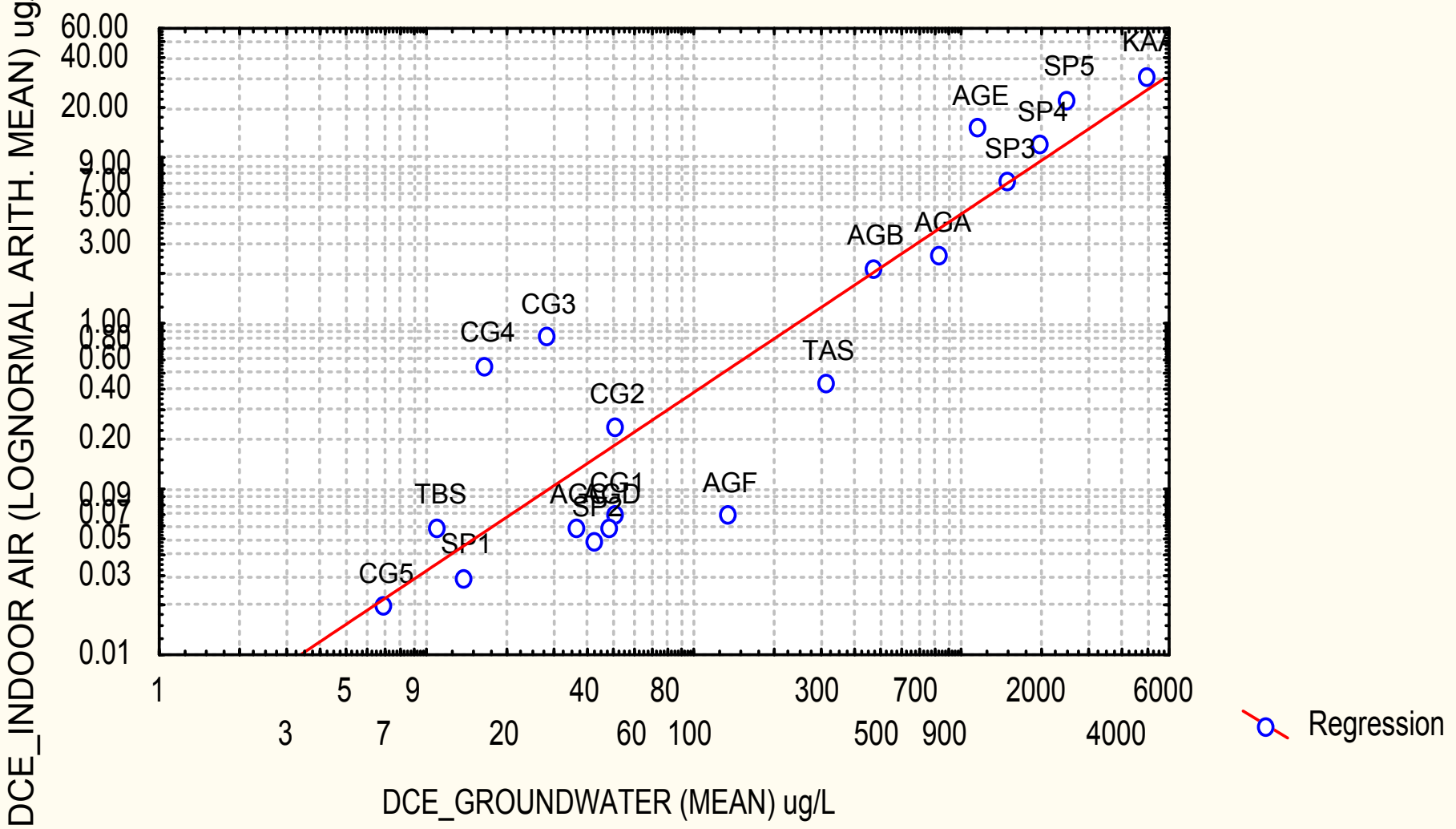
- The large amount of data and good spatial coverage produced excellent inter-media correlations for three COCs in groundwater and indoor air (TCA, DCE, TCE)
- The impact of background TCA and TCE is quite apparent on the correlation plots, resulting in the correlations being much better at higher groundwater concentrations.
- Soil vapor data was not well correlated with either groundwater or indoor air and was not considered useful for indoor air modelling

DCE_GROUNDWATER vs. DCE_INDOOR AIR (NEAR & MID PLUME APARTMENTS)

DCE_IA = -.0549 + .00705 * DCE_GW

Correlation: r = .95977

DATA THOUGH JAN 1998



TCE in Groundwater Correlated with TCE in Indoor Air(Near & Mid Plume)

LOGTCEIA = -.6346 + .32353 * LOGTCEGW

Correlation: r = .68923

Data through January 1998

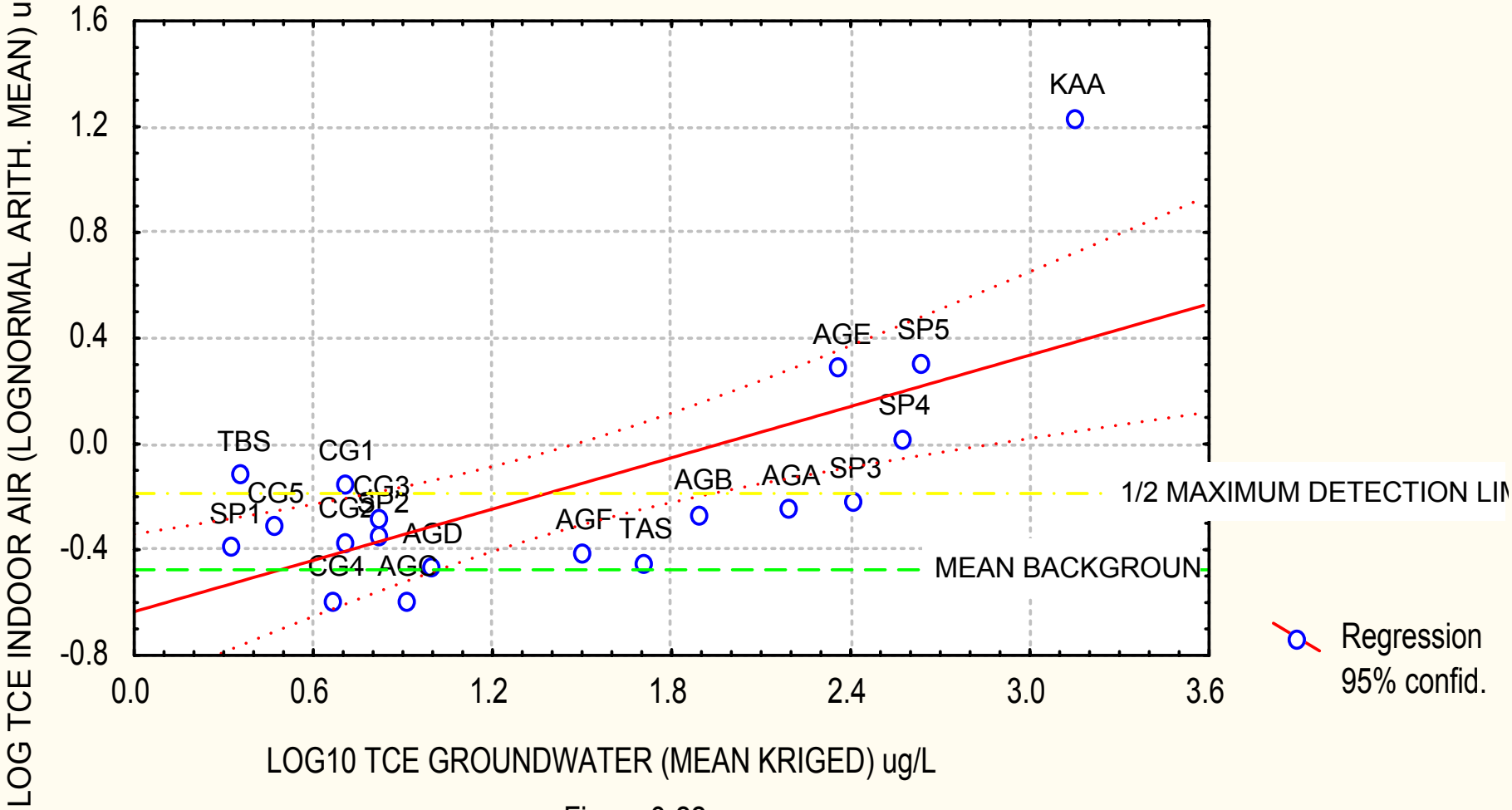


Figure 3-22

TCE in Groundwater Correlated with High TCE in Indoor Air (Near & Mid Plume)

LOGTCEIA = -2.024 + .90916 * LOGTCEGW

Correlation: r = .87467

high groundwater concentrations only (through January 1998)

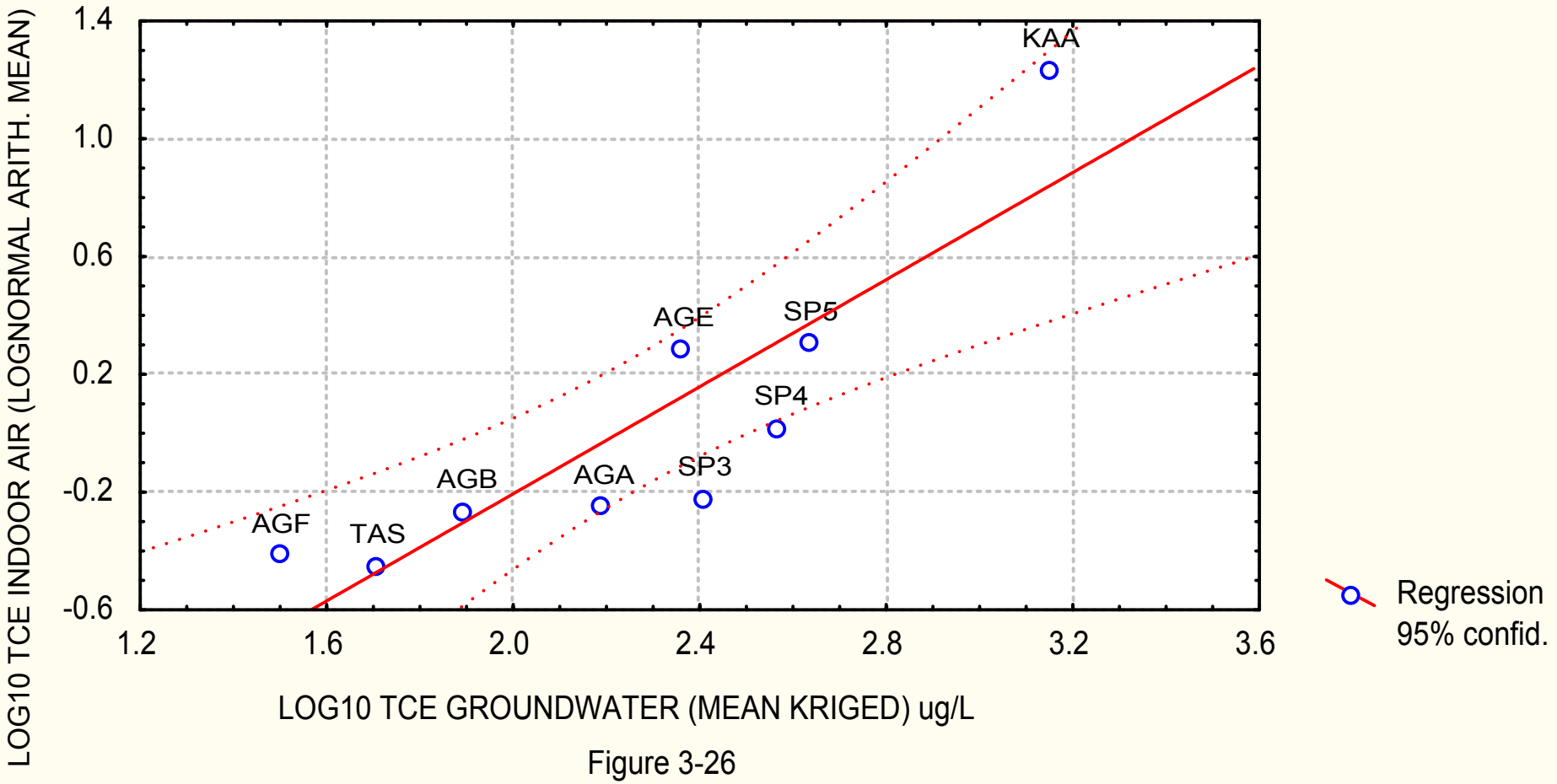
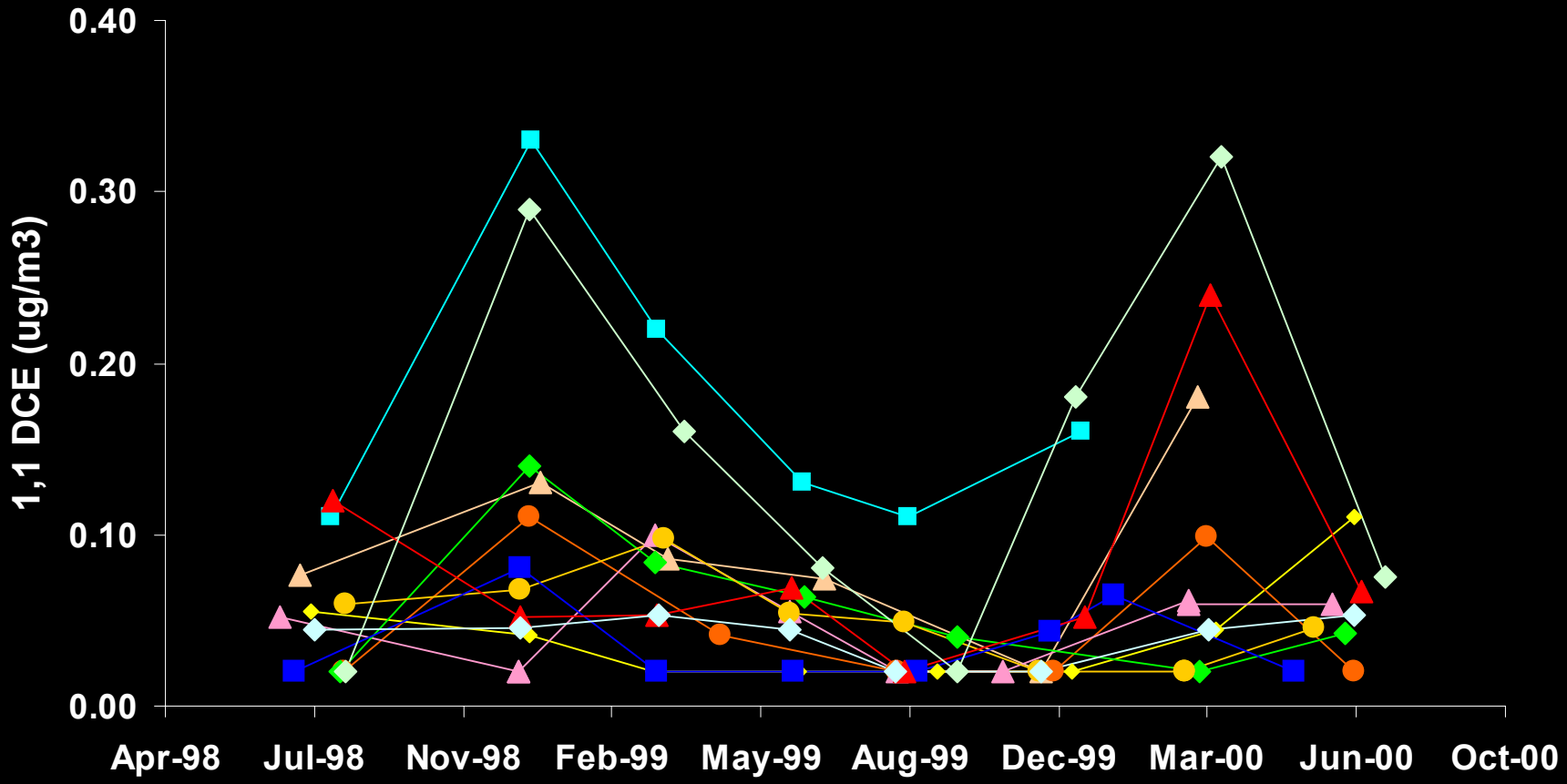


Figure 3-26

Seasonal Variations
Verification Monitoring Data

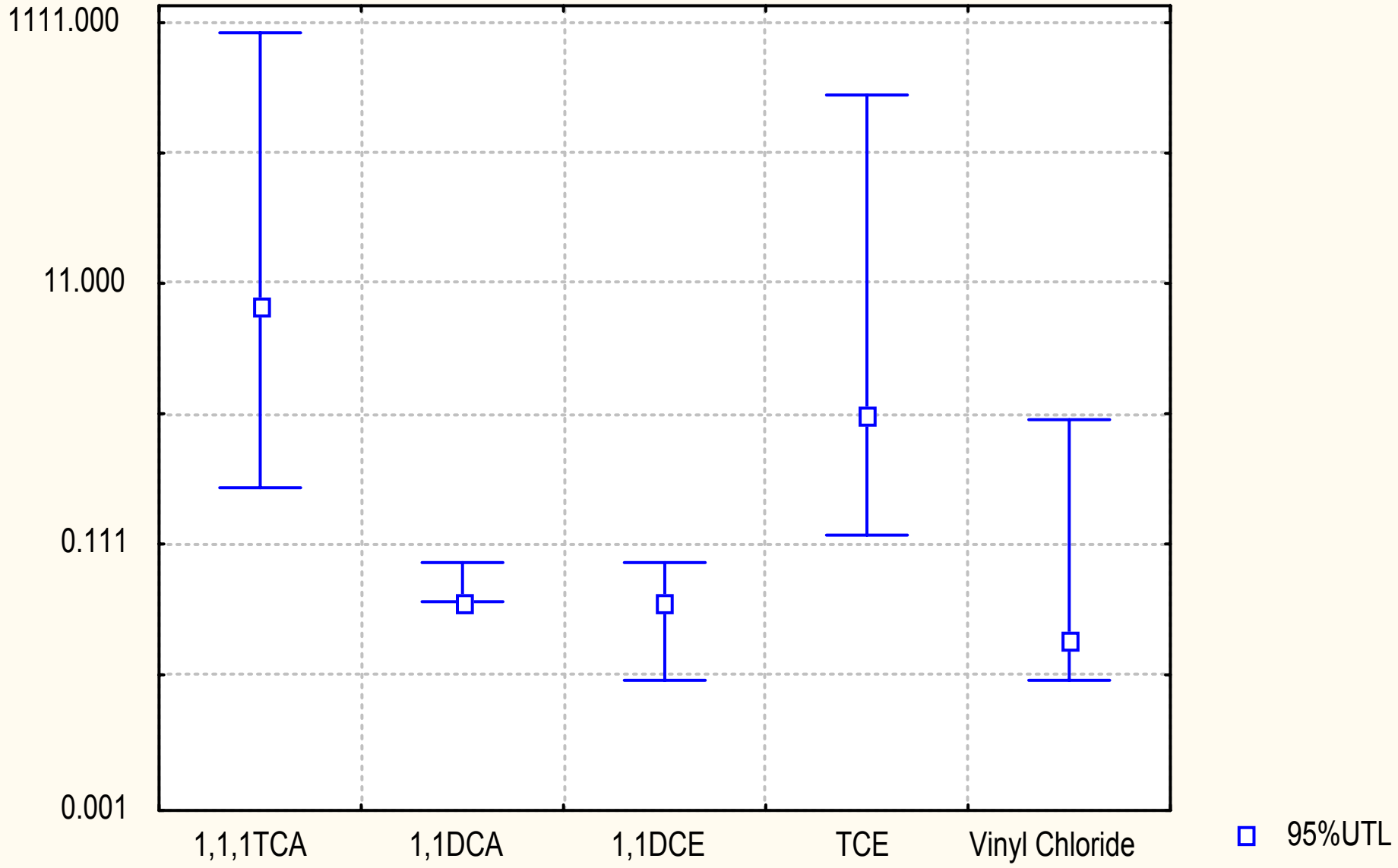


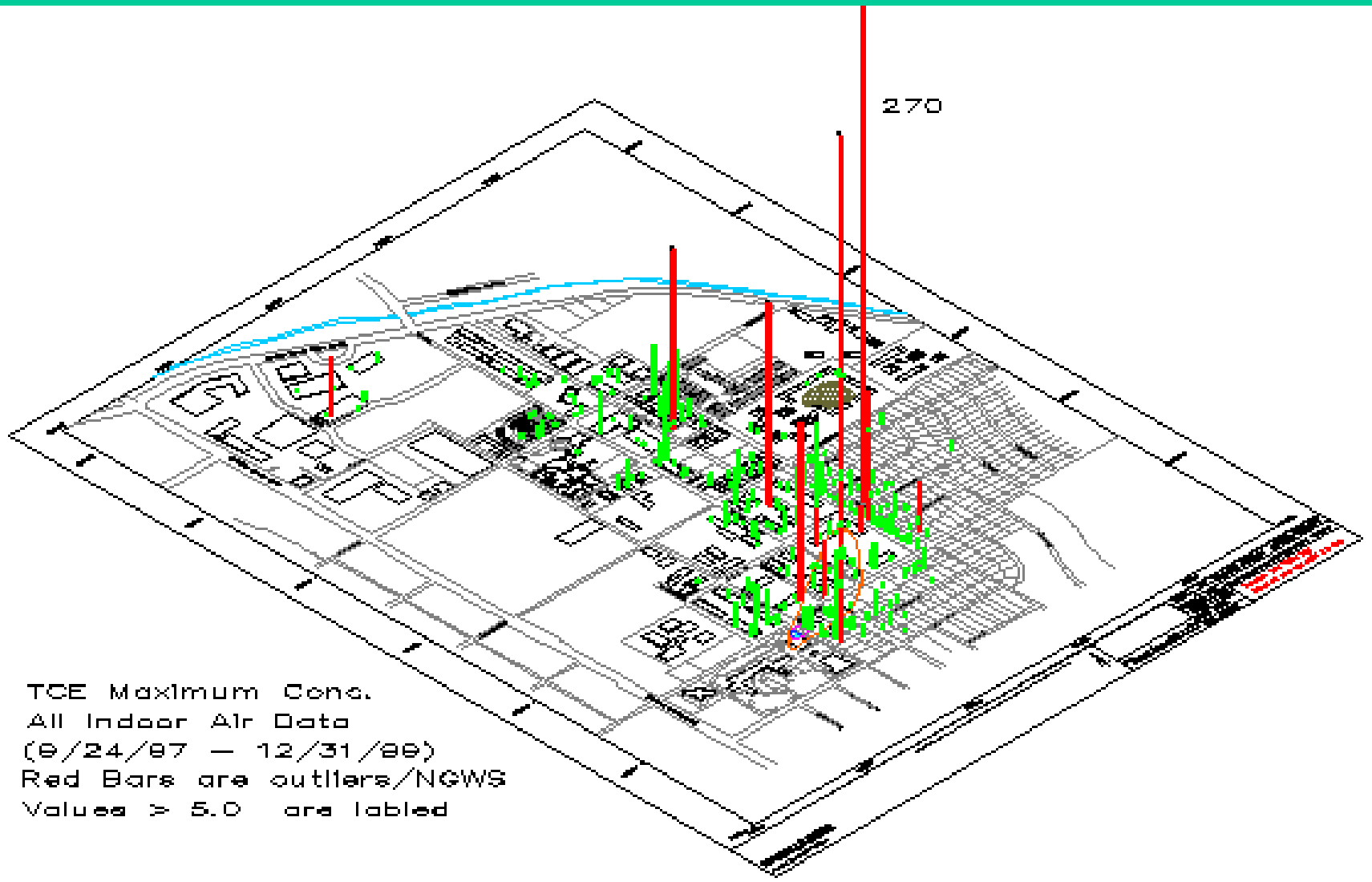
CDOT BACKGROUND DATA

- The very large database of low detection limit indoor air samples included several subsets of data useful for background determination (post remediation samples and samples specifically collected at background locations)
- The very large ranges in background concentrations for TCA, DCM, TCE and PCE are notable

Range Plot (Background Residential Indoor Air)

Denver-Boulder, Colorado




270
TCE Maximum Conc.
All Indoor Air Data
(9/24/97 — 12/31/99)
Red Bars are outliers/NGWS
Values > 5.0 are labled

MITIGATION SYSTEM

- RADON ABATEMENT SYSTEM
- CREATE A LOW PRESSURE ZONE BELOW THE HOUSE EITHER THROUGH SUB-SLAB OR SUB-GRADE DE-PRESSURIZATION.

Vapor Mitigation in Colorado CDPH&E & Region 8

- CDPH&E calls for vapor removal (>10-5 risk)
- CDOT (as of early ‘99)
- 27 Homes (single family - no basements)
- 5 Apartment Buildings (vapors up to 5th flr)

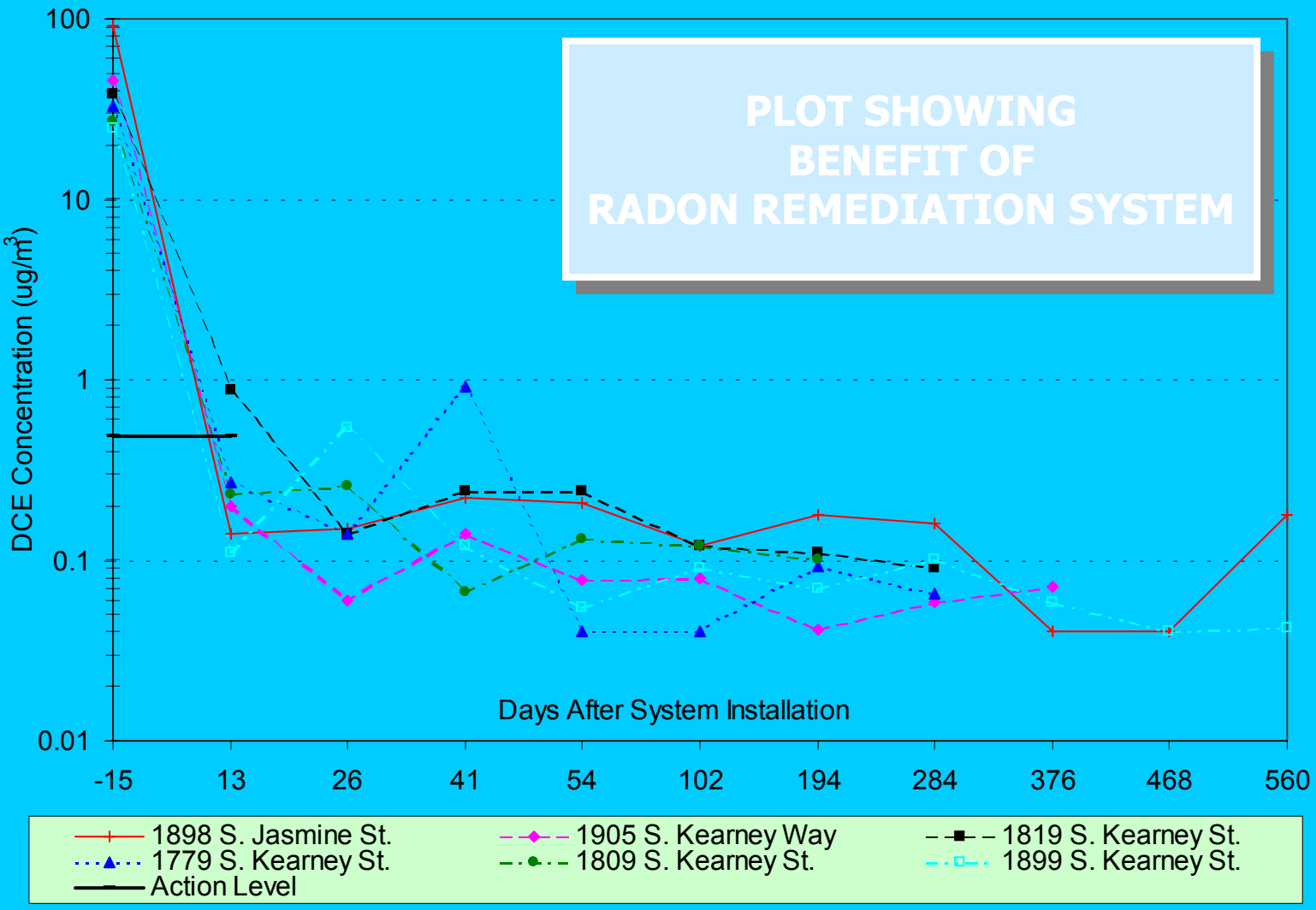
- Nearby facilities 100’s of homes (2001)
- (Colorado DEP&H & Region 8)

REDFIELD SITE

EnviroGroup Ltd.

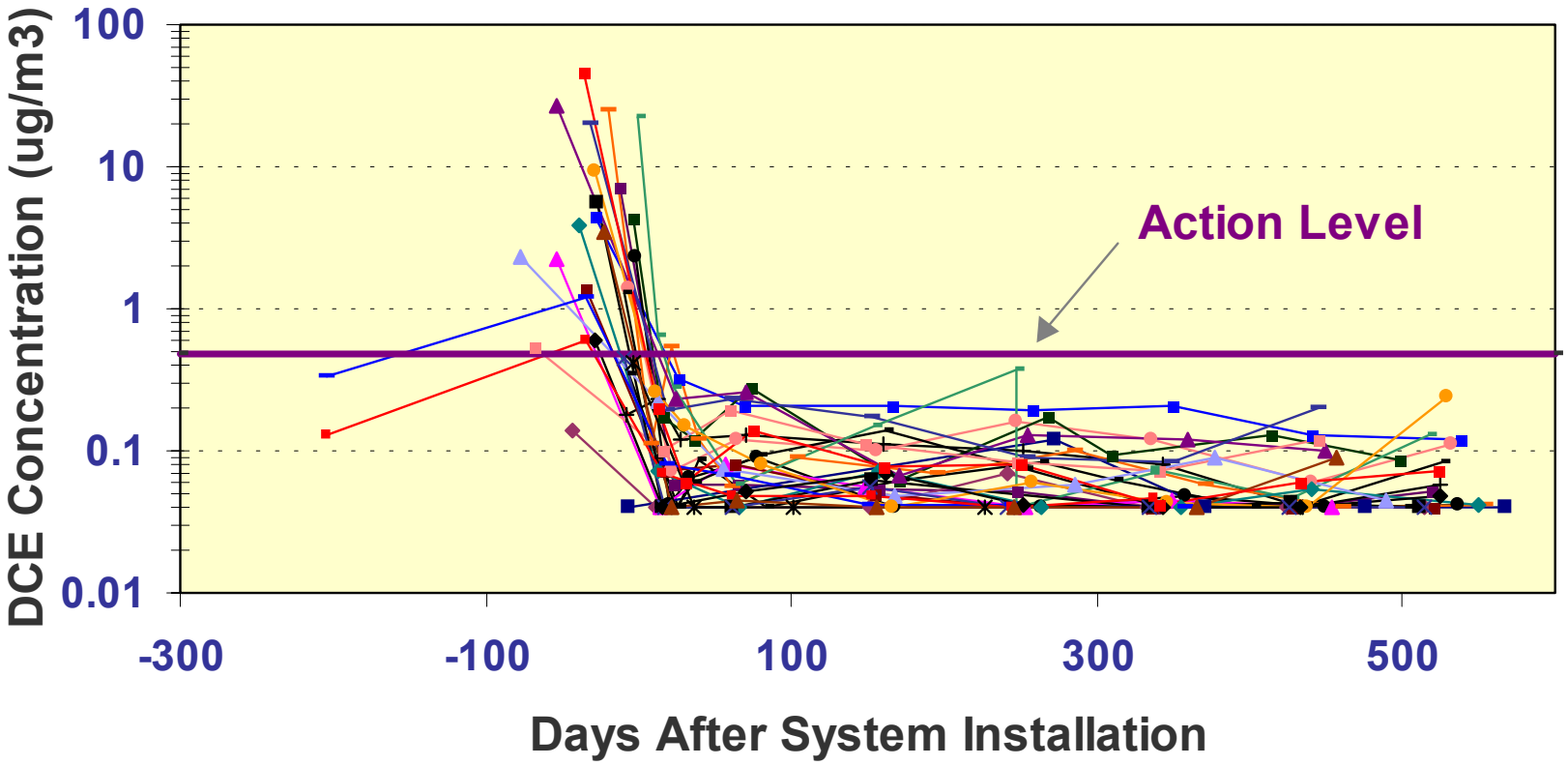
REDFIELD IAQ TEST DATA

INITIAL DCE = >24 UG/M3

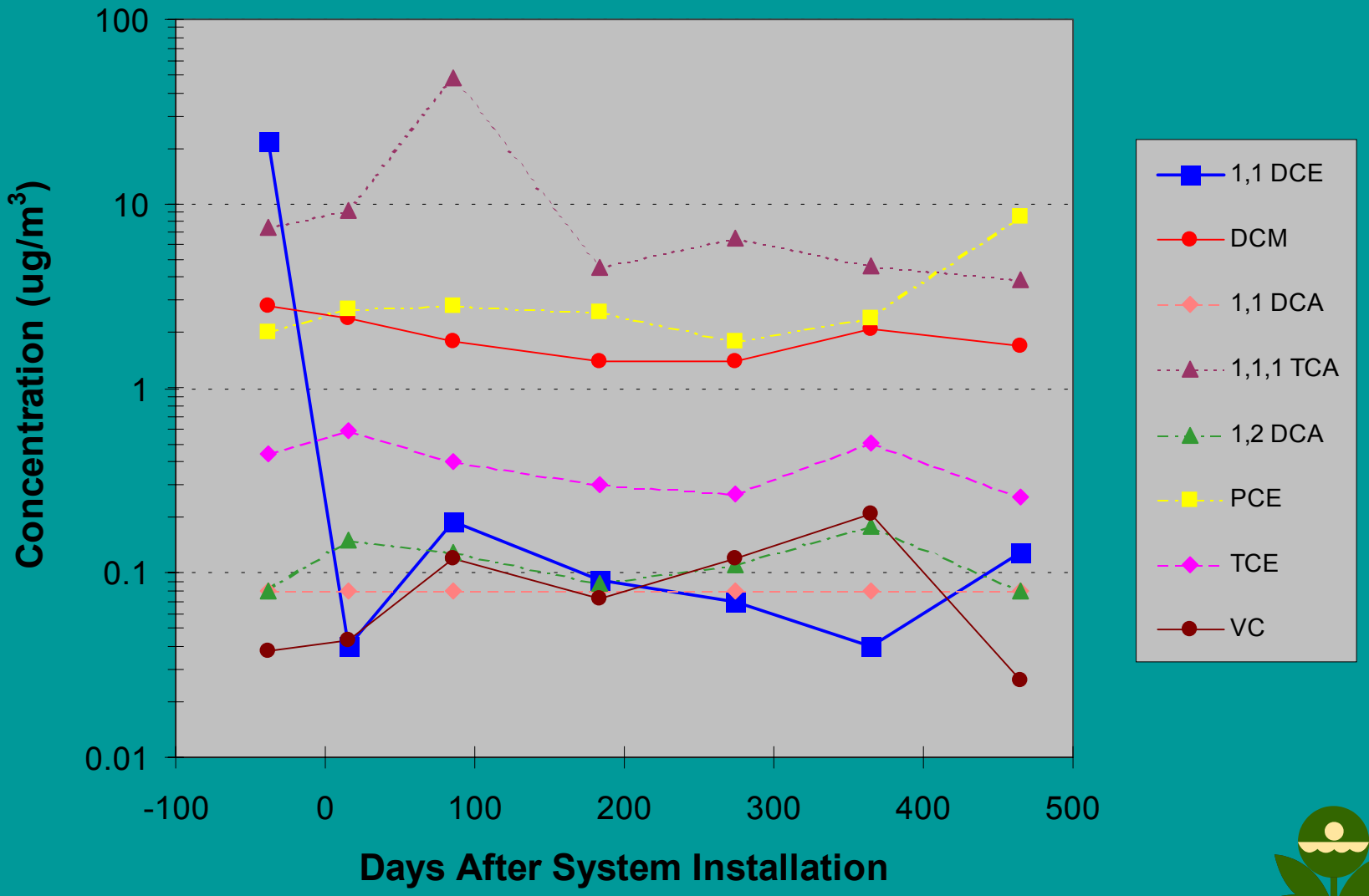


SUB-SLAB SYSTEM PERFORMANCE

NO MODIFICATIONS REQUIRED



BACKGROUND VOC LEVELS IN MITIGATED HOMES



Risk due to Indoor Air

(for VOCs)

- Can greatly exceed those due to exposures more commonly considered in cleanup programs, such as:

- Ingestion of contaminated groundwater (1% of exposure, (including shower ?)),
- and
- Ingestion and/or dermal contact with soil

- *(However, may not exceed everyday exposures from consumer products and everyday activities)

Connecticut Cleanup Criteria

- For 1,1-DCE:
- Groundwater Ingestion 7 ug/l
- Protection of Indoor Air 1 ug/l

CHRONIC EXPOSURE AIR BENCHMARKS

AT 10^{-5} RISK LEVEL

SUBSTANCE	*ug/M^3	PPB
PCE	43	6.35
TCE	14	2.61
1,1 - DCE	0.49	0.12
1,2 - DCA	0.94	0.23
Vinyl Chloride	0.29	0.11
Methylene Chl	3.1	0.89

$$*ug/M3 = \frac{ppb \times MW}{24.45}$$

Comparison of

Groundwater Ingestion and Inhalation Exposures Factors

Factors	GW Ingestion	Inhalation
Amount of media/day	2 Liters	20,000 Liters (20 m3/d)
Route of Entry	Gastrointestinal	Airways & Lungs
Local toxicity	Low?	Higher?
Degraded (pre-absorp)	Maybe	Less likely ?
Area for Absorption	5 m2 ?	100 m2
Absorption Rate	?	Higher ? (chem. specific)
Ease of avoidance	Easy (alt. H2O)	Difficult (No alt. Air)

CONCLUSIONS

- Screening methods & models are imprecise (at reasonable investigation costs)
- Indoor air testing requires patience
- Standard radon systems work well up to 99.5% efficiencies if installed carefully
- background concentrations may be significant for many VOCs
- Pathway is important- Need RAF Workgroup?
- Frequency =?

Vapor Intrusion Web sites

- Excel and Lotus versions of all models as well as User's Guide are available on the EPA Superfund Risk Assessment Web Site at:

www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm

- http://www.clu-in.org/EIForum2000
- 8 hours of presentations on Indoor Air exposure pathways (audio and slides)